# DOCUMENT RESUME

ED 299 117 SE 049 634

| | |
|---|---|
| TITLE | The Role, Education, and Qualifications of the High School Physics Teacher. High School Physics--Views from AAPT. |
| INSTITUTION | American Association of Physics Teachers, Washington, D.C. |
| PUB DATE | 88 |
| NOTE | 19p. |
| AVAILABLE FROM | American Association of Physics Teachers, 5112 Berwyr Road, College Park, MD 20740 (first 9 copies free, 10 or more $1.00). |
| PUB TYPE | Viewpoints (120) |
| EDRS PRICE | MF01/PC01 Plus Postage. |
| DESCRIPTORS | Higher Education; High Schools; *Inservice Teacher Education; Methods Courses; *Physics; *Preservice Teacher Education; Science Careers; Science Education; *Science Teachers; Secondary Education; *Secondary School Science; Teacher Certification; Teacher Education; *Teacher Education Programs |
| IDENTIFIERS | *American Association of Physics Teachers |

ABSTRACT

The teacher is one of the most important variables for maintaining or developing excellence in education. According to many surveys many teachers of high school physics earned their degrees in other fields. This paper deals with preservice and inservice high school physics teacher education. Topics include: (1) what physics teachers are expected to do; (2) physics knowledge background (including physics courses in the undergraduate program and fifth year program); (3) professional skills (including pedagogy, management of a classroom and laboratory, and ways of guiding and motivating students); (4) suggestions for teachers with various backgrounds; (5) suggestions to physics departments in colleges and universities about course offerings; (6) certification; and (7) trends in teacher education. The appendix includes examples of certification requirements from Massachusetts and Wisconsin. (YP)

# The Role, Education, and Qualifications of the High School Physics Teacher

High School Physics—Views from AAPT



Published by
American Association of Physics Teachers

American Association of Physics Teachers
5112 Berwyn Road
College Park, MD 20740
(301)345-4200

1988, Prepared by the AAPT Committee on Special Projects for High School Physics

# The Role, Education, and Qualifications of the High School Physics Teacher

CONTENTS



*High School Physics: Views from AAPT* includes several papers published by the American Association of Physics Teachers (AAPT), 5112 Berwyn Road, College Park, MD 20740. They concern resources and policies needed to match high school physics teaching to its responsibilities and opportunities. The present document was prepared by the AAPT Committee on Special Projects for High School Physics, whose members were Donald Barron, Robert Beck Clark, Carole Escobar, William C. Kelly, John W. Layman, Katherine Mays, Jim Nelson, Joe P Meyer, and Jack M. Wilson, in cooperation with the AAPT Committees on High School Physics and Professional Concerns.

## 1. THE TEACHER—KEYSTONE OF QUALITY

Excellence in high school physics depends on many things: the teacher, course content, availability of apparatus and time for laboratory experiments, a clear philosophy and workable plan for meeting students' needs, serious dedication to learning goals, and adequate financial support. The role of the teacher, however, is the most important. Without a well-educated, strongly motivated, skilled, well-supported teacher, the arch of excellence in high school physics collapses. The teacher is the keystone of quality.

## 2. OVERVIEW

This paper deals with the education of high school physics teachers, both prospective teachers and teachers in service. The recommendations set forth here reflect the realities of teaching in the modern world and the goals and ideals of the physics teaching profession.

Many more students should study physics in high school. Our society is technologically based and would benefit greatly if more of its citizens comprehended the principles of physics. Informed voting on such issues as energy policy, protection of the environment, safety of nuclear plants, and disposal of nuclear wastes is aided by an understanding of basic physics. Strengthening the economy, preparing for technological change, and meeting economic competition from abroad also demand a better educated work force: more and better physics education is one important part.

The most vital element in physics education is the teacher. A well-prepared and effective teacher is essential. Many teachers of high school physics, however, earned their degrees in other fields. Some have little or no background in physics. Others have an excellent background. AAPT wants to encourage all to assess their preparation in physics and seek the goal of an excellent background in physics if they have not already achieved it.

We begin with a reminder of what physics teachers are expected to do in U.S. high schools (Section 3). They have a widely varied set of responsibilities, not all of which have to do with physics teaching.

To meet these responsibilities, physics teachers first need a knowledge of physics (Section 4). An excellent background in physics consists of an undergraduate preparation in physics, mathematics, and related sciences equivalent to a physics major. Specifically, the undergraduate education should include:

- An introductory course in college physics
- Courses above the introductory level:
  - Mechanics
  - Electricity and Magnetism
  - Modern Physics
  - Heat and Thermodynamics
  - Optics
- Associated laboratory work, use of calculus, use of the computer, and studies in related sciences and mathematics.

To teach introductory college-level or Advanced Placement courses in high school, the physics teacher should also take graduate work in physics and professional education to the master's degree.

Physics teachers must be effective in the classroom as well as competent in physics. Professional skills—pedagogy, management of a classroom and laboratory, ways of guiding and inspiring students—must be acquired (Section 5) if the physics teacher is to be an excellent teacher as well as an excellent physicist

A teacher who lacks the preparation outlined above should acquire it expeditiously. Such a teacher of physics needs to add intermediate courses in physics and mathematics in his or her background, achieving a minor in physics as an early goal, but going on to the equivalent of a major. We consider (Section 6) various situations—"excellent background," "minimal background, "limited background," and "no background"—and suggest courses of action in each. School districts need to assist their physics teachers in acquiring this additional preparation and becoming involved in professional associations. The professional associations also have a role to play. A related matter is the availability of suitable physics courses for teachers; we offer several suggestions to physics departments in colleges and universities about course offerings (Section 7).

The subject of certification—the official stamp upon qualification—comes up next (Section 8). We discuss the role of the states and describe several examples of state requirements for certification in physics (Appendix A). We conclude (Section 9) with a brief presentation of trends in teacher education, as indicated in recent reports.

## 3. WHAT DO WE EXPECT OF THE TEACHER?

Probably no other profession makes its demands in more varied ways than teaching. In addition to the well-known requirement of a scholarly professional education, the teacher's job ideally calls for the organizing skill of an executive, the friendly warmth of a counselor, the sensitive human understanding of the psychiatrist, the inspirational leadership of an evangelist, the audience contact of the actor, the sense of responsibility of the surgeon, and an ability characteristic particularly of teaching to operate effectively and with satisfaction at the level of young people.

A physics teacher must also have subject-matter mastery, technical understanding, considerable mechanical skill, and a willingness to continue studying for an entire professional life to keep abreast of this rapidly changing field. Talents and traits of this order are not easily found or cheaply hired by schools against the competition of industry, which wants its employees to have most of these same qualifications. Yet money spent on the salary of a good teacher is well spent when we consider the influence the teacher will have on the development of generations of students.

In addition to inspiring and guiding *all* pupils to their best efforts, a teacher has charge of one of our great national assets—our gifted youth—at the age when they are most impressionable. Gifted people often mature at an early age. Albert Einstein, for example, did the work in physics for which he is most famous before he was 26. James Clerk Maxwell, whose electromagnetic equations form the basis for the entire electrical and communications industry today, presented his first paper before the Royal Society at the age of fourteen. Examples among our contemporaries can also be cited. Much development in the lives of people such as these takes place at the high school age. Surely our nation should not be content with anything less than the best possible instruction for them.

Physics teachers spend most of their school hours in the science classroom, conducting class discussions, giving demonstrations, or supervising laboratory work. The average class size in physics is about 20 students, but it may go up to 30 or more in some instances. Ordinarily there is only one teacher instructing physics classes. In some schools, however, where enrollments are larger, there may be several physics teachers. They work together to give the students the best physics courses, often of several different kinds.

Not all of the teaching duties will be in physics. Although there are a few full-time physics teachers in U.S. high schools, statistically most teachers of physics classes also teach other subjects—usually physical science, other sciences, or mathematics. We shall discuss the implications of multiple-subject teaching assignments for teacher education.

Conducting scheduled classes is only a part of the physics teacher's workload. Physics teachers estimate that about 70% of *in-school* time is spent teaching students. An additional 15% of the *teacher*'s time is spent providing supervision (homeroom, study halls, lunch duty, etc.). This leaves only about 15% of the teacher's *in-school* time for preparing laboratory experiments and demonstrations, maintaining equipment, ordering equipment and supplies, course planning, testing (writing tests, grading, checking problem solutions and laboratory notebooks), supervising project work by students, participating in committee work and administrative conferences as a member of the school faculty, sponsoring extracurricular school activities (some science-related, others not), and holding conferences with students and their parents. Clearly the amount of time provided for these last activities is insufficient, and the teacher spends several hours per day of *out-of-school* time performing these essential functions.

The physics teacher must also keep up to date; usually this means journal reading or attending classes or professional meetings in the evenings, on week-ends, or during school vacation periods. He or she may take part in local, state or national curriculum-revision projects or may write laboratory materials; this, too, is "off-duty" work. The physics teacher's professional life is a full one.

## 4. EXCELLENT ACADEMIC PREPARATION IN PHYSICS: A GOAL

Of the many desired characteristics of the physics teacher, one that can be assessed fairly and in an impersonal way is academic preparation. This preparation can be analyzed within three categories – the studies of a broad and comprehensive nature which contribute to the teacher's general education; professional studies in areas of education, such as learning theory and pedagogy, necessary for work as a teacher; and preparation in the subject matter field. Of the first we shall say relatively little here. But the preparation of the physics teacher in physics and in professional education related to physics teaching needs attention. The physics teacher must be well grounded in the subject. Unlike English, mathematics, or social studies, physics – at present – is not common knowledge and is less likely to have been studied by a majority of students. And while teachers of some other subjects may gain knowledge by reading and study, it is very difficult to build a background in physics without formal instruction. For these reasons we shall describe in some detail the desired preparation in physics for someone who plans to teach physics. Since effective performance in the classroom is also important, professional education needs discussion, too.

It should be noted at the outset that many competent groups have addressed the problem of the education of physics teachers during the last three decades In addition to the American Association of Physics Teachers,[1] one can cite the American Physical Society,[2] Commission on College Physics,[3] the American Institute of Physics,[4] the National Science Teachers Association,[5] the American Association for the Advancement of Science,[6] and the National Research Council.[7] Although the reports of these groups differ in organization and in the emphases they place on different aspects of teacher education, they are remarkably unanimous in regard to the recommended preparation.

**To possess an excellent background in physics, a teacher of high school physics courses should have an undergraduate preparation in physics, mathematics, and related sciences equivalent to a physics major. Furthermore, to teach introductory college-level courses or Advanced Placement courses and to guide gifted students effectively, such a person should pursue graduate studies in physics and professional education to the master's degree.**

In brief, the undergraduate preparation should include the following

- An introductory course in college physics
- Five courses above the introductory level (intermediate courses):
  - Mechanics
  - Electricity and Magnetism
  - Modern Physics
  - Heat and Thermodynamics
  - Optics
- Associated laboratory work, use of calculus, use of computers, and studies in related sciences and mathematics.

Short descriptions of these courses follow.

*Physics Courses in the Undergraduate Program:*

*Introductory Course in College Physics:* This should be a course which pursues in depth basic principles of physics and the great unifying concepts. Some of the most important topics are Newton's Laws of Motion; Conservation of Mass, Energy, and Momentum; Electromagnetism; Waves; Fields; Molecular Structure of Matter; Structure of the Atom; and Introduction to Contemporary Physics (Applications of Basic Physics in Cosmology, Elementary Particles, Solid State Physics, and Relativity). Problem solving and laboratory experience are important aspects of this course. The laboratory especially must give first-hand experiences and knowledge of how a physicist approaches an experimental problem and should provide an introduction to the use of computers.

*Intermediate Courses in Physics:* The prospective high-school physics teacher should have a one-semester intermediate course (post-introductory level, calculus-based) in each of these areas: Mechanics, Heat and Thermodynamics, Optics, and Electricity and Magnetism. Emphasis should be on thorough quantitative treatment of a limited number of topics in these areas of classical physics; the goal should be a deep understanding of the basic principles. There should be some advanced laboratory work and work with computers associated with these courses. A few institutions may be able to offer this material in one substantial, multi-semester, integrated course, which is given especially for prospective teachers These courses should be based on calculus and progressively use differential equations, numerical solution of equations, and other mathematical methods as applied in physics.

*Modern Physics:* The development of Atomic, Nuclear, Solid-State, and Elementary Particle Physics should be traced through study of the phenomena, concepts, and experiments which are important to the understanding and appreciation of these newer areas of physics. Relativity and Cosmology should be introduced as important unifying concepts. Again the number of topics considered should be consistent with the goal of understanding emphasized above. This course should utilize the mathematics background of the student and should have a well-developed laboratory portion that includes the use of computers.

*Studies in Related Sciences and Mathematics:* To meet multi-subject teaching assignments, physics teachers should take a considerable amount of work in related sciences, usually chemistry or biology. The courses in the field chosen should include the introductory course and several intermediate courses, constituting at least a minor in the field. Laboratory and problem-solving work should be stressed.

Other science courses may be selected from the following:

1. Astronomy
2. Geology
3. Meteorology
4. A course combining two or more of 1 through 3 when an institution is able to do this interestingly and well.
5. Introductory Chemistry or Introductory Biology – if not part of the minor.
6. A computer science course, at a level between that of a "computer literacy" course and one taken by computer-science majors, is also recommended. It should provide an introduction to programming in one or more of the common programming languages.

The mathematics courses should include calculus and introductory differential equations. An introductory course in "modern mathematics applied to physics," including elements of statistics, probability, and vector analysis, is also strongly recommended.

*Fifth Year Program:*

In working toward an advanced degree, the physics student-teacher should explore more deeply the classical foundations of physics as well as new areas of knowledge emerging from contemporary research. Although the graduate physics curriculum for teachers should be more pedagogically oriented than the undergraduate one, it should include sizable amounts of physics and mathematics as well as additional laboratory work.

*Summary of Educational Goal**

The curriculum proposed above as an educational goal provides a strong preparation in physics and mathematics as well as substantial work in other sciences. This transdisciplinary preparation is not only educationally beneficial, but professionally desirable and realistic. In addition to providing the teacher with greater breadth of understanding of science, the broader preparation recommended recognizes that most physics teachers are expected to teach courses other than physics – typically chemistry, mathematics, or physical science. The majority of U.S. secondary schools offer no more than one or two classes of physics, and a significant fraction offer physics only in alternate years. The physics teacher needs to prepare to teach other subjects. We have therefore suggested that at least twenty-four semester hours be taken in one or more of the other basic sciences. The choice will usually be chemistry, but we suggest that biology – increasingly mathematical and based on physical principles – also be considered. Some teachers will want to elect mathematics or Earth sciences as a second field of concentration, instead of chemistry or biology.

*The reader may seek a translation of our recommendations into the common terminology of academia - the "semester hour." This is not easy to do because colleges and universities differ greatly in the ways they assign academic credit to courses of comparable requirements. The numbers in Table 1 should be regarded as illustrative national averages, rather than precise requirements of recommended subjects by a particular college or university.

Table 1. A Goal for Academic Preparation of High-School Physics Teachers in Physics and Related Fields (Semester hours)

| SUBJECTS | FOUR YEAR TOTAL | FIFTH YEAR | FIVE YEAR TOTAL |
|---|---|---|---|
| Physics | 32 | 16 | 48 |
| Chemistry, Biology, or other Science | 24 | -- | 24 |
| Mathematics | 16 | 6 | 22 |
| TOTALS | 72 | 22 | 94 |

## 5. PROFESSIONAL EDUCATION

A physics teacher should have sufficient courses in pedagogy and pedagogical theory to become a skilled teacher and to be able to keep up with developments in the profession of teaching. In the undergraduate years, a limited number of effective courses should be devoted to the basics of professional education. These courses should provide a good introduction while not involving such a time commitment on the part of the student as to preclude attaining the perspective and knowledge afforded by a liberal arts curriculum and strong preparation in physics. In graduate school, teachers will usually take additional professional education courses, but these should include work in pedagogy specific to physics education.

It is important that any prospective teacher—and some teachers in service who missed these things in their earlier education—acquire skills and strategies for promoting learning. Obviously, physics teachers should possess those skills that are special to physics teaching: the maintenance of a laboratory, the construction and grading of laboratory activities, demonstrations, and safety practices in the physics laboratory. Courses in teaching/learning should also contribute procedures for dealing with the mechanics of teaching (e.g., how to use educational equipment, how to grade tests, how to combine marks for a total student grade), with the mechanics of classroom administration (e.g., how to write goals and objectives for a class and how to use standardized tests to adjust teaching strategies), and with educational research on pedagogy (e.g., how to decide what sort of examination to use, and how to write appropriate test questions).

Coursework combined with observing master teachers and evaluating one's own teaching experience can have valuable products: problem-solving strategies, ways of detecting and correcting learning difficulties, understanding of the different learning styles of students, and ways of inspiring and leading young people to greater intellectual achievement. Even the method of asking questions may have a profound effect on the progress of students and often distinguish the master teacher from the novice. We emphasize therefore that pedagogic skills, as well as a sound grasp of physics, must be gained by the physics teacher. Although this paper dwells on the latter, reflecting what we perceive as a national need to do so, "excellent physics teacher," in our opinion, means "excellent teacher" as well as "excellent physicist."

A physics teacher also should have a solid background in the mechanics of writing. The teacher should set a good example of English usage (both spoken and written) for students. The teacher should demand correct usage from students and help them overcome their difficulties in expressing ideas.

Finally, we mention the need of high school physics teachers to be educated in the history of their subject—itself a fascinating study!—and in the social implications of discoveries in physics and their technological applications. Normal treatment of such matters in physics courses may be insufficient for these future mentors of high school students. Priorities and overcrowding of the curriculum must be considered, however, and we do not recommend required courses in these topics. Instead, the use of electives, minicourses, undergraduate colloquia, and recommended-reading lists should be considered.

## 6. THE SPECTRUM OF PREPARATION

The qualifications of the nation's physics teachers, when analyzed according to academic preparation, form a broad spectrum. There are teachers with excellent backgrounds in physics, teachers who have minimal backgrounds in physics, teachers who are in great need of supplementary preparation in physics,and teachers with little preparation at all. In a physics-teaching population of around 19,000, several thousand have excellent backgrounds in physics; several times this number have less than an excellent physics background; and all too many others have almost no formal physics education for the classroom role that school staffing difficulties force them to assume. How should this problem be solved for teachers in each part of the preparation spectrum?

First of all, AAPT recognizes that some teachers have compensated for lack of classroom instruction in physics by home study, diligent learning from colleagues, and taking advantage of many informal opportunities to learn physics. It is difficult to generalize fairly about individual cases. Although some "non-major" physics teachers are indeed excellent classroom teachers, we urge them to reassess how current and complete their education in physics is and whether it fully supports excellent teaching. If their conclusion is not strongly positive, some of the suggestions made below may be helpful.

*The Teacher with Excellent Physics Background.* The teacher whose record shows a background of undergraduate and graduate course work such as that recommended above – a full major in physics, significant graduate work, and a firm grasp of teaching skills – can be considered to be well prepared in the subject area. The school district with one or more teachers of this caliber should congratulate itself. But even a well-prepared teacher needs to keep up-to-date. This teacher has probably shown alertness to the growth of physics by taking additional courses. As a rough estimate, at least one course or workshop might have been taken in any five-year period. Such work is usually done by evening, weekend, or summer study at a college or university, but perhaps the teacher has been a member of a special summer institute or workshop or has prepared to give such a workshop. Well-prepared physics teachers can benefit from internships, fellowships, or summer jobs sponsored by industrial companies. In some localities, industry, national laboratories, and professional societies offer valuable lecture courses for science teachers.

The well-prepared teacher also maintains competence in physics by membership in professional associations such as the American Association of Physics Teachers (5112 Berwyn Road, College Park, MD 20740), the National Science Teachers Association (1742 Connecticut Avenue, N.W., Washington, D.C. 20009), and state and local science teachers' organizations. He or she attends their meetings and reads their journals. *The Physics Teacher* and the *Announcer* of the American Association of Physics Teachers are especially valuable to the high school physics teacher. The first contains articles and special sections dealing with physics and physics teaching, almost all of them applicable to the high school classroom. The second contains important news for physics teachers – calendars and programs of meetings, listing of workshops and institutes, and news of new publications. Well-prepared teachers who are active in their profession are well qualified to contribute journal articles and to give talks at regional and national meetings, and many do so regularly. Attending professional meetings provides strong motivation and much-needed peer interaction.

*The Teacher with Minimal Physics Background.* This teacher has a bachelor's degree with a major in some area other than physics, often chemistry, biology, or mathematics. In addition, he or she has had a substantial amount of undergraduate work in physics (e.g., a minor in physics but not a major). Such a person seems to us to have a minimal academic preparation for physics; the teacher's academic preparation falls short of the goal described above. We recommend, once again, an assessment by the teacher and by his or her academic advisors of strengths and weaknesses in the teacher's academic preparation in physics and mathematics. Such an assessment should be followed by the development and implementation of a plan for any needed supplementary course work, with the goal of eventually achieving the preparation outlined in Section 4.

*The Teacher with Limited Physics Background.* Having probably majored in a related science or mathematics, this teacher has usually had an introductory course in physics and at least one intermediate physics course – around 15 to 18 semester hours total in physics – and a year or two of college mathematics. This type of background is insufficient for the effective teaching of physics. While the teacher might be able to lead students along a well-marked path, it is too much to expect him or her to plan a course or laboratory work effectively, to inspire superior students to extra efforts, or to bring about the kind of appreciation and insight that is the expected outcome of a superior physics course.

The teacher with the type of formal preparation just described – and no supplementary preparation – needs additional education in physics. It would be especially valuable for this person to take several intermediate courses, to study modern physics, to obtain extra laboratory experience, and to study the historical development of physics concepts. The school district should encourage and assist the teacher in every possible way to obtain this needed background.

**To meet teaching responsibilities effectively in physics, the teacher whose physics background is limited should acquire at least the equivalent of an undergraduate minor in physics and do so as soon as possible, preferably through formal course work.** We suggest that intermediate courses (with laboratory work) in mechanics, electricity and magnetism, modern physics, optics, and heat and thermodynamics be considered. (Heat and thermodynamics may already have been taken by teachers who majored in chemistry.) Preparation in mathematics needs to be assessed and may also require strengthening. In some localities, late afternoon, evening, or Saturday courses may be available, and summer sessions sometimes include suitable courses in physics. (A list of institutions offering undergraduate physics programs can be obtained from the American Institute of Physics, 335 East 45th Street, New York, NY 10017).

It must be recognized that such course work is both intellectually demanding and time consuming. The teacher with a full schedule of teaching, activity sponsorships, and other school duties probably cannot carry more than four semester hours of college work at any time during the academic year without serious impairment of effectiveness. A school can help its physics teacher improve knowledge of the subject by relief from part of the school load. This relief may take the form of freedom from routine chores such as monitoring the cafeteria and halls, custodial or clerical assignments, and activity sponsorships and committee meetings, and of providing a teaching assignment that does not require an unusual number of separate daily preparations. Arrangements enabling the physics teacher to complete training will provide an ultimate reward to students that will far outweigh the inconvenience of the moment.

Workshops and institutes are also available to help physics teachers. Each meeting of the American Association of Physics Teachers (in January and June) includes a number of special workshops for one or two days – often with "hands-on" experience – in subjects of vital interest to physics teachers. Examples are "Use of Computers in Physics Teaching," "Developing Student Confidence in Physics," and "Use of Demonstrations." Further information about these workshops and about summer institutes offered by colleges and universities will be found in the *Announcer* or obtained by writing to the American Association of Physics Teachers.

The teacher with a limited physics background needs, even more than the well-prepared one, the support that membership in national and regional organizations of teachers can provide. Our suggestions on page 7 may apply.

*The Unprepared Teacher.* It is unfortunate that many teachers with little or no preparation in physics are called on to teach physics. These persons seldom can do so effectively. In the hands of a poorly prepared teacher, the physics course becomes a routine of reading the text, finding words to fit spaces in a workbook, and working problems by substituting numbers for letters in algebraic formulas. Questions may be unwelcome because the teacher does not know the answers. If offered at all, the explanations may be incomplete, evasive, and inaccurate. Laboratory work, if done, is "cookbook style"; expensive equipment is neglected on the storage shelf, or if used, may be damaged. It is a thoroughly frustrating experience for pupils. It is even more unpleasant for the teacher.

Assigning the physics course to a teacher who lacks any preparation in physics or whose preparation is greatly out-of-date should be regarded as justifiable only in an emergency and on a temporary basis. This teacher desperately needs the support and encouragement of colleagues. If he or she is to continue in the assignment, training in physics should begin without delay. The comments and suggestions made above about the further education of "the teacher with limited physics background" are even more cogent here. Also cogent is the recommendation that the school district be supportive of further education.

**The unprepared teacher should first take a college or university course in introductory physics (with laboratory) at the highest level at which he or she can benefit. This should be followed by intermediate courses with the goal of achieving an undergraduate minor in physics as soon as possible. Mathematics through introductory calculus is also recommended.**

The inexperienced and poorly prepared physics teacher should be given special assistance. This is properly a function of the department head, but might be assigned as a part of the professional load to another physics teacher of known skill and experience. Regular consultations should deal with planning and progress of the course and particularly with laboratory preparation and the handling of equipment. The American Association of Physics Teachers has prepared a "Resource Kit for the New Physics Teacher" containing suggestions for those teaching physics with little preparation on how to get started. Write to the AAPT.

The physics teacher with inadequate background in physics should use a proven syllabus or course outline. Such a syllabus might be obtained from an experienced colleague or from suitable publications. (For example, see the AAPT paper entitled "Course Content in High School Physics.") Use of the table of contents of a physics textbook as a guide to syllabus formation is not recommended. Most textbooks contain more material than should be covered in a one-year course. Thus, selectivity is essential in order to avoid either superficial treatment of an excessive number of topics or omission of some fundamental parts of physics which happen to be at the end of the book. Excess focus on the text may also lead to insufficient attention to laboratory work.

Concern about the situation of physics teachers with limited or no background in physics has led the American Association of Physics Teachers, with the assistance of the National Science Foundation, to create a special resource

for physics teachers: the program of Physics Teaching Resource Agents (PTRAs). In 1985 and again in 1986, over 100 experienced teachers of high school physics have been brought together each summer to attend workshops in physics and physics education, and to receive training to become local resources for physics teaching. These teachers have gone back to their own localities to work on local programs for improving physics in high schools. They have instituted after-school workshops for teachers, provided advice for new teachers, worked with local colleges and universities to plan physics courses for teachers, encouraged teachers to attend meetings of AAPT Regional Sections, and collected information about local needs. Now a group of over 300 persons, PTRAs form a national network that is expected to continue to provide these services. For further information and a list of names and addresses, write to the AAPT.

Other organizations are also working to assist the schools: the American Physical Society (335 East 45th Street, New York, NY 10017), which has an active Education Committee and a College-High School Interaction Committee; the American Association for the Advancement of Science (1333 H Street, N.W., Washington, DC 20005); and the Triangle Coalition (1742 Connecticut Avenue, N.W., Washington, DC 20009).

## 7. PROVIDING APPROPRIATE PHYSICS COURSES

Both prospective physics teachers and teachers in service report that they have encountered difficulties in finding suitable physics courses among the regular offerings of colleges and universities. Most institutions of higher education do not offer special physics courses for teachers. Prospective teachers must enroll in the same physics courses as future doctoral physicists. This has caused difficulties of two kinds: 1) the pedagogic goal of teachers-to-be is lost sight of, and 2) the pace, mathematical rigor, and—some would say—style of the courses have been more suitable for future researchers than for future teachers. The obvious solution of providing separate courses for teachers is often not available to colleges and universities because of the small enrollments. Nevertheless, some physics departments are seeking to solve this problem and have reported success.[8,9]

AAPT urges all physics departments to review their course offerings with prospective high school teachers in mind to ensure that everything possible is being done to meet their needs. We offer the following suggestions:

*Regional cooperation.* Several colleges and universities can join forces to devise a suitable sequence of intermediate, undergraduate physics courses for teachers, with transferable credits, and to share the responsibility of offering them on a rotational plan in a geographic region of reasonable size. Pre-service and in-service teachers need the assurance that physics courses they require to complete or update their preparation will be available when needed, within reasonable commuting distance, and at convenient times. Physics departments should consider offering some of the regular courses late enough in the day for teachers to attend them after school.

*Graduate credit.* Colleges and universities should allow teachers to submit for graduate credit toward the M.Ed. degree intermediate physics courses usually taken by physics majors in the junior or senior undergraduate years.

*Pedagogic seminars.* When it is not possible to offer special intermediate courses for teachers, physics departments should consider offering in parallel with the regular courses, special one-credit pedagogic seminars to relate the physics content of the intermediate physics courses to the high school classroom.

*Faculty guidance.* Physics departments should designate at least one faculty member in each institution, for whom the task is congenial and compatible with other responsibilities, to direct high school physics teacher programs. Such a person should monitor the progress of students in these programs, counsel them, and take a leading role in planning and teaching the courses.

*Participation by experienced high school teachers in conducting courses.* The responsibility for designating teachers of the courses belongs to the faculties of the colleges and universities offering them. Physics departments should keep in mind, however, that there is a valuable teaching resource in those local high school physics teachers who have excellent backgrounds and great experience. As part-time or adjunct teachers, such persons can be an important asset in conducting courses for less well-prepared and inexperienced teachers, both pedagogic courses (dealing with management of the teaching laboratory, giving demonstrations, applying new approaches to physics in the classroom, etc.) and, in some cases, regular intermediate courses.

Teachers need laboratory work in their preparatory experience. The intermediate laboratory in particular should be given careful attention in planning courses for teachers. It offers the hands-on, one-on-one kind of teaching that will help high school teachers develop their own teaching styles and acquire the scientific and pedagogic skills needed to present physics effectively and safely as an experimental, inquiry-based science.

## 8. CERTIFICATION – THE LICENSE TO TEACH

The foregoing suggestions for the education of prospective physics teachers and for supplementary education of practicing teachers with limited physics background have, of course, no legal basis. Requirements for certification to teach are set by each of the 50 states and enforced by state departments of education working with local school districts, which are the actual employers. Certification requirements are devised to meet each state's perception of its educational needs and of the standards it wishes to maintain in the preparation of teachers in its schools. These differ greatly from state to state, but it is fair to say that public awareness of the need to raise the nation's educational achievements has stimulated the states to review and, in many instances, modify their requirements for certification, especially in regard to the requirement for evidence of adequate subject matter competence. The suggestions we have offered are fully consistent with this trend.

Certification requirements in many states are changing. As a result of a national survey conducted in 1985 with the cooperation of the Council of State Science Supervisors, Robert Beck Clark of Texas A&M University reported:

> Some 29 states have revised their certification requirements, and 16 more states are considering such changes. Of particular interest are the so-called alternative certification programs that have been adopted in California, Florida, New Jersey, and Texas. These programs allow individuals with degrees in areas in which they desire to teach to become teachers without taking the usual college education courses. In the Texas program, with which I am most familiar, a teacher is hired at the normal starting salary by a district that has been approved for this program, and is given a normal teaching assignment. But during the first year, he is identified as an intern and supervised by a master teacher. The hiring district assumes responsibility for providing during the first year the pedagogical training that might be required. If the teacher's performance is adequate, full certification is granted at the end of that year.[10]

It is not possible in the limited space available here to include the present certification requirements in all 50 states. As examples of those in effect in states that have recently completed a revision, the summary of requirements in Massachusetts and Wisconsin (Appendix A) may be helpful.

State requirements in physics may differ somewhat from the qualifications described in this paper. The differences are usually small and can be attributed to different requirements for general education, which overlap the requirements in the major subject to some extent. AAPT believes that the principles we have recommended are sound and are consistent with the trends in state certification requirements. We recommend, however, that prospective physics teachers and practising teachers consult their state departments of education for the latest statements concerning certification.

## 9. ON THE HORIZON

Not only certification requirements, but also the role, status, and rewards of the teacher are undergoing inspection in U.S. society. Concern about the quality of pre-college education in this country has prompted consideration of what must be done to attract and retain a greater number of well-educated, enthusiastic, professional teachers. Following earlier reports[11,12] that sounded a general alarm about the shortcomings of our schools, several recent reports have focused almost entirely on the education and status of the teacher.

The Holmes Group, a study group of deans of education at several dozen research universities, called on higher education to reform teacher education and the profession of teaching.[13] The Holmes Group stated its goals to be:

- "To make the education of teachers intellectually more solid;"
- "To recognize differences in teachers' knowledge, skill, and commitment in their education, certification, and work;"
- "To create standards of entry to the profession – examinations and educational requirements – that are professionally relevant and intellectually defensible;"
- "To connect our own institutions to schools, and"
- "To make schools better places for teachers to work and to learn."

Their analysis of the task of reaching these goals led to far-ranging recommendations for change, including an end to undergraduate education majors and a new approach to certification of teachers. The latter would provide a three-level system of teacher categories: "career professionals," "professionals," and (temporary) "instructors."

The Task Force on Teaching as a Profession, which was established by the Carnegie Forum with the support of the Carnegie Corporation of New York, began its report with a review of the essential role of education in maintaining the competitive position of the United States in a changing world economy.[14] It described the educational task ahead as major "challenge" to this country and put foremost in its analysis "the crucial function of the teacher." Like the Holmes Group, the Task Force called for a sweeping reform of teacher education and a restructuring of the teaching profession. It also advocated the creation of a "National Board for Professional Teaching Standards" to increase certification requirements; urged major changes in salaries and career opportunities for teachers to strengthen the profession of teaching and make it more competitive with other fields; recommended a greater effort to recruit and educate members of minority groups for teaching careers; and proposed changes in schools to increase the teachers' discretion in meeting local and state education goals, while holding them responsible for their students' progress.

The two reports cited have identified worthy goals and presented convincing evidence of the need for change in teacher education and the public concept of the teaching profession. The road to the goals is not made completely clear, and the author groups admit that the road may be long and difficult. The reports are on firm ground in sensing that the U.S. public is concerned about education. It remains to be seen whether that concern will be matched by a public commitment to provide the resources needed.

Two things are already quite clear in these reports and undoubtedly will appear in reports in the future. The balance between subject-matter competence and "other teaching competence" is swinging back toward the former. In that regard, the suggestions AAPT has made about education in physics for physics teachers seem very much in tune with the times. The other is that both reports have stressed the importance of involving professional groups of teachers in the task of overhauling teacher education and giving a new look to the teaching profession, deeming a concern for such matters as one of the hallmarks of a profession. It is in this spirit of concern that the American Association of Physics Teachers has prepared this document and its companion documents.


## AN ACKNOWLEDGMENT

AAPT wishes to acknowledge the important role played by an earlier publication in inspiring this report and providing portions of the text for its first draft. *Physics in Your High School*, a handbook prepared by Thomas D. Miner and William C. Kelly under the auspices of the American Institute of Physics, was published by the McGraw-Hill Book Company in 1960. Although now long out of print, it served to stimulate local discussion about improving physics courses in many communities of the United States for a decade or so. Chapter IV – "The Physics Teacher" – provided many helpful suggestions and felicitous phrasings for the present document. In place of detailed citations of the borrowed text, which was subsequently edited for this report, we acknowledge here with thanks the many contributions of this predecessor.


## 10. REFERENCES


(1) Peter Lindenfeld and Jack Wilson, eds , *Conference on Teacher Institutes and Workshops*, AAPT Topical Conference Series (1985).

(2) "A Statement Concerning the Need for Improvement of Precollege Science and Mathematics Education," APS (1984).

(3) *Preparing High School Physics Teachers*. Commission on College Physics (1968)

(4) *Physics in Your High School*, American Institute of Physics (1960) *loc. cit.*

(5) "Recommended Standards for the Preparation and Certification of Secondary Teachers of Science," NSTA Position Statement, *The Science Teacher*, December 1984, p. 57.

(6) *Science Teaching: The Report of the 1985 National Forum for School Science*, American Association for the Advancement of Science (1986).

(7) *The State of School Science*, National Research Council (1979).

(8) E. Leonard Jossem, "How to Overcome Obstacles at the Colleges: Commitment and Support, Credits, Standards, and Degrees", *Conference on Teacher Institutes and Workshops, loc cit.*

(9) Lillian C. McDermott "An Example of a Teacher Education Program in a Physics Department The University of Washington," *Conference on Teacher Institutes and Workshops, loc. cit.*

(10) Robert Beck Clark, *Physics Today*, December 1985, page 44.

(11) *A Nation at Risk: The Imperative for Educational Reform*, U.S. Department of Education, 1983

(12) *Educating Americans for the 21st Century: A Report to the American People and the National Science Board*, National Science Foundation, 1983.

(13 ) *Tomorrow's Teachers: A Report of the Holmes Group,* Holmes Group, Inc., 501 Erickson Hall, East Lansing, MI 1986.

(14) A *Nation Prepared: Teachers for the 21st Century*, Carnegie Forum, 1986

# APPENDIX A

## CERTIFICATION REQUIREMENTS OF STATES: EXAMPLES FROM MASSACHUSETTS AND WISCONSIN

**Massachusetts***

2 *Classroom Teacher. (Common Standards)*

(a) *Standard I.* The effective teacher is knowledgeable in the field proposed for certification (The competencies required to meet this standard are listed under each classroom teaching certificate.)

(b) *Standard II.* The effective teacher communicates clearly, understandably, and appropriately. To meet this standard, the candidate will demonstrate that he or she:

1. gives clear and concise explanations and directions
2. frames questions so as to encourage inquiry
3. uses appropriate metaphors, examples, and illustrations
4. makes the goals of teaching and learning clear to students
5. uses language appropriate to the age, developmental stage, special needs, and social, racial, and linguistic background of his or her students
6. serves as an example of clear and effective oral and written communication
7. listens to students
8. communicates effectively with parents

(c) *Standard III.* The effective teacher designs instruction to facilitate learning consistent with the needs and interests of the learners and so as to maintain a sense of order and purpose in the classroom. To meet this standard, the candidate will demonstrate that he or she:

1. understands the needs and interests of his or her students and designs or adapts the curriculum to meet these needs and interests
2. has clear goals for student learning
3. relates the elements of instruction sequentially to each other, to other fields of knowledge, to students' experiences, and to long-term goals
4. understands developmental psychology, and relationships between stages of growth
5. uses materials, media, and techniques appropriate to the age, developmental stage, special needs, and social, racial and linguistic background of his or her students, both individually and as a class
6. uses materials, media, and techniques suited to the subject matter and to meeting the goals of instruction
7. teaches, as necessary, the basic academic skills (reading, communication, mathematics) related to the goals of instruction
8. is aware of recent developments in teaching, particularly in his or her field(s) of knowledge
9. understands techniques of classroom management and how to maintain a sense of order in the classroom
10. makes effective use of appropriate resources in the community

(d) *Standard IV.* The effective teacher uses the results of various evaluative procedures to assess the effectiveness of instruction To meet this standard, the candidate will demonstrate that he or she

1. uses *evaluative procedures* appropriate to the age, developmental stage, special needs, and social, racial, and linguistic background of his or her students, and corrects for any ethnic,

*From *Regulations for the Certification of Educational Personnel*, Massachusetts Board of Education, Quincy, Massachusetts. September 1982, page 24.

racial, or sexual bias in evaluation
2. interprets the results of evaluative procedures, and uses these results to improve instruction both for the class as a whole and for individual students
3. identifies problems in reading which inhibit learning and works toward remedying these problems
4. encourages the involvement of students in evaluation of instruction
5. evaluates his or her own role, behavior, and performance in the classroom

(e) *Standard V.* The effective teacher is equitable, sensitive and responsive to all learners To meet this standard, the candidate will demonstrate that he or she:
1. defends and encourages the exercise of students' rights to equal treatment and freedom of expression
2. responds to the needs of individual students so as to enhance their self-esteem
3. works toward a learning environment favorable to open inquiry and devoid of ridicule
4. encourages a positive atmosphere for all students, especially those with special needs
5. avoids and discourages racial, sexual, social, ethnic, religious, physical, and other stereotyping.

*15 Teacher of Physics*

(a) *Requirements*
1. completion of 36 semester hours of course work in physics as defined under Standard I, below
2. completion of a pre-practicum consisting of 21 semester hours of course work and other experiences as defined in common Standards II - V (7.04 (2) (b) - (e) )
3. completion of a practicum judged successful on the basis of Standards I -V

(b) *Standard I.* The effective physics teacher knows:
1. physics in general, including mechanics, heat, light, sound; electricity and magnetism, atomic physics; and related aspects of mathematics
2 modes of inquiry and methods of research and experimentation in the sciences, including laboratory techniques
3 relationships between physics and other fields of knowledge

**Wisconsin ****

*PI3.08 Secondary education.* (7-12). A regular license may be issued to applicant who has completed the general requirements in PI 3 05, including the Approved Program and the institutional endorsement, and the following:

(1) An applicant shall have completed a teaching major of at least 34 semester credits or a teaching minor of at least 22 semester credits if certified in another area with a major
(2) A minimum of 18 semester credits of professional education is required including:
  (a) Educational psychology or psychology of learning;
  (b) Methods of teaching (at least in major subject); and
  (c) Student teaching - a minimum of 5 semester credits.

History: CR. Register, October, 1984, No. 346, eff. 11-1-84

*PI3.12 Science subject areas.* A regular license may be issued in the following subjects to an applicant who has completed the general requirements in PI 3.05, the secondary education requirements in PI 3.08, and a minimum of 8 semester credits in other science subjects. Certification on the basis of completion of a minor in a science subject may be obtained only if the applicant has completed the broad field science major or a major in another science subject except that with a major in mathematics and a minor in physics, certification in physics may be obtained. Any additional requirements are noted below.

**From *Wisconsin Administrative Code, Register*, October 1984 No. 346, page 19.

(1) Biology, Life Science - 605

(2) Chemistry - 610

(3) Conservation - 615

(4) Earth and Space Science - 635

(5) Physical Science - 637. Effective July 1, 1980, the regular license to teach chemistry - 610, physics - 625 and physical science - 637 in grades 7 through 12 may be issued to the applicant who has completed a 44 semester credit major in physical science, including:

(a) Twenty-two semester credits in chemistry; and

(b) Twenty-two semester credits in physics.

(6) Physics - 625

(7) Broad Field Science - 601. Effective July 1, 1980, the regular license in broad field science which permits the teaching of all sciences in grades 7 through 12 (except biology - 605, chemistry - 610, earth science - 635, and physics - 625 in grades 10 through 12) may be issued to the applicant who has completed:

(a) A 54 semester credit major in science, including:

1. Fourteen semester credits major in each of 2 of the following
   a. Biology
   b. Chemistry
   c. Earth science
   d. Physics
2. Eight semester credits in each of the remaining 2 sciences.
3. Ten additional semester credits selected from:
   a. Biology
   b. Chemistry
   c. Earth science
   d. Physics
   e. History of science
   f. Philosophy of science
4 Six semester credits in mathematics.

(b) Upon the request of a school district administrator, a person holding a license to teach science based on the broad field science teaching major but not meeting the credit requirement for extending certification to the specific subject in grades 10 through 12 may be issued a 2 year nonrenewable license to teach: biology - 605, chemistry - 610, physics - 625, or earth science - 635.

In such cases the teacher shall complete required course work during this 2-year period to be eligible for a regular teaching license.

(8) Science - 621. Effective July 1, 1984, an applicant who holds secondary science licenses based upon at least a major in one science and a minor in another science shall be issued a license to teach science in grades 7 and 8 and general science in grade 9. An applicant who holds a secondary science license and who has completed the program listed in par. (a) shall be issued a license to teach science in grades 7 and 8 and general science in grade 9. An applicant who holds an elementary education license to teach grade 8 and who has completed the program listed in par. (a) shall be issued a license to teach general science in grade 9. Licensed elementary teachers may teach science at those grade levels for which they are licensed.

(a) An elementary education license or a secondary science license and 28 semester credits to include:

1. 10 semester credits in one of the following:
   a. Biology;

b. Chemistry;

c Earth and space science; or

d. Physics

2. A minimum of 6 semester credits in each of the three remaining subjects

(b) Secondary science licenses based upon at least a major in one science and a minor in another science.

*4.42 Science: Common Rules.* Professional education programs leading to certification in science shall meet the following common standards:

(1) The program shall require study of the history of science including development of scientific thought and the philosophy of science including assumptions, ethics, and limitations of science.

(2) The program shall require study and experiences designed to develop knowledge and skills in problem solving including data gathering and data analysis and using the results of the analysis to make explanations.

(3) The program shall require study of the interaction of science and society including political, economic, and sociological implications.

(4) The program shall require study and experiences designed to develop knowledge and awareness of environmental issues.

(5) The program shall require laboratory and field experiences in the science areas studied

(6) The program shall require study designed to develop knowledge and skills in laboratory management and use; laboratory safety procedures and practices, special science laboratory techniques.

(7) The program shall require study of mathematics as it is applied in the practice of science.

*4.47 Physics.* A professional education program leading to certification in physics shall meet the following standards:

(1) The program shall require study of interrelationships of matter and energy, mechanics of static and dynamic systems, electromagnetic phenomena, and atomic and molecular structure of matter.

(2) The program shall require study and experiences designed to develop competence in quantitative laboratory measurement and application of mathematics to solving physical problems.

American Association of Physics Teachers